Subsonic Microphone

using a low-cost electret insert

by K.-H. Kopp

Commercially-produced subsonic microphones are too expensive for the cost-conscious user. However, as long as a high-precision measuring device is not what is required, you can build such a microphone yourself using a few components from the spares box.

The job of a microphone is to convert a sound into an electrical voltage as faithfully as possible. The conversion happens in two stages: first from sound into mechanical form in the microphone capsule, and then from mechanical into electrical form in the transducer itself. The chief characteristics of a microphone are its directional response and its frequency response. The directional response is only of peripheral interest to us here: it is the frequency response that concerns us more. How can a microphone, which according to its specifications has a frequency response starting at say 50 Hz, be made to respond to infrasound at frequencies below a few Hertz? To answer this question, we first need to go into a little theory.

The frequency response of a microphone is determined jointly by the action of the capsule and the transducer. Here we distinguish between dynamic types, such as the ribbon and moving coil microphones, and electrostatic types, such as the condenser microphone. Microphones employing other types of transducer, such as crystal, carbon or contact microphones, are now only of historical interest.

If we wish to construct an economical and simple microphone, the choice of transducer type is easy: only the electret microphone, which operates on the condenser principle, is worth considering. Many different electret capsules are readily available and they are inexpensive. They require no capsule supply voltage, since the membrane (diaphragm), or electrode, is made of an electret material (generally based on a PTFE film) which has received a permanent electric charge by electron bombardment. In higher-quality electret microphones the back electrode is also made of charged electret material.

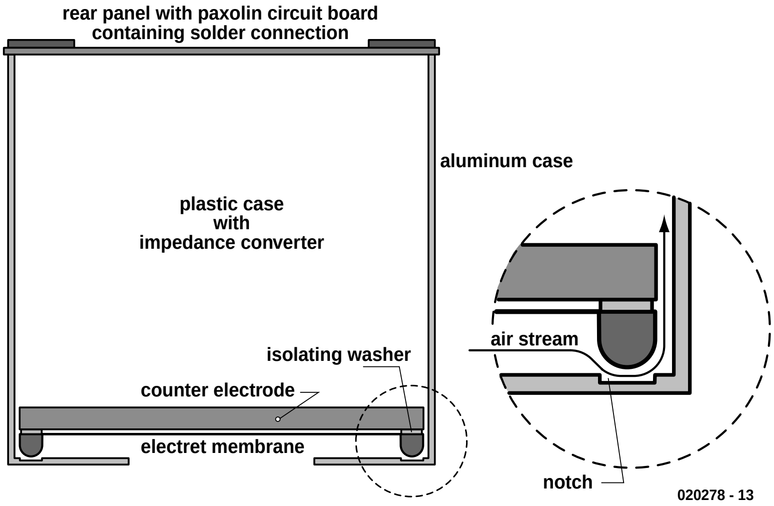

Figure 1. Cross-section through an electret microphone capsule.

Figure 1 shows an electret microphone in cross-section. The electret diaphragm is fitted to the front side, and a short distance behind it is the back electrode. The diaphragm is laid on an insulating ring. The majority of the capsule consists of a plastic body containing a tiny impedance converter (a simple FET stage). The tiny Paxolin circuit board on which the impedance converter is built also serves as the rear panel holding the connection terminals. The whole thing is fitted into a small aluminium tube with rolled edges.

Pressure and pressure gradient transducers

If an electret microphone is examined closely, a very tiny feature will be found that nevertheless has far-reaching consequences for its frequency response: there are notches in the rim of the aluminium enclosure, under the insulating ring. Air movement is possible through these notches between the front and the rear of the diaphragm (membrane). This changes the capsule from a pressure transducer into a pressure gradient transducer.

Figure 2 shows the main difference. In a pressure transducer the diaphragm moves outwards when the external pressure is low (a trough in the sound wave), and inwards when the pressure is high (a peak in the sound wave). However slowly the air pressure changes, the diaphragm will (at least in theory) always be displaced. In practice pressure transducers are equipped with a capillary hole which allows slow equalisation of pressures as the atmospheric pressure changes. Matters are different with the pressure gradient transducer. Here the displacement is a result of difference in path lengths and hence difference in sound pressure (or gradient) between the front and rear sides of the diaphragm. It is not necessary to express this behaviour in a formula to see that the pressure gradient becomes smaller and smaller as the frequency is reduced. The response of the pressure gradient transducer to very low frequencies is very weak, in stark contrast to the pressure transducer, which in theory can operate down to 0 Hz.

Ingredients

All it is necessary to do to construct a subsonic microphone, then, is to convert the pressure gradient transducer into a pressure transducer — for example, by sealing up the notches with glue. That is fine in theory, but is unfortunately not practicable since the delicate diaphragm will be damaged by the glue. Instead, we can simply replace the enclosure. Since not everyone will have access to a lathe to turn up a sealed made-to-measure enclosure, the author has found that standard components can be misused to make a suitable enclosure.

Take a phono line socket, a stereo jack plug (3.5 mm) and a BNC socket with cable gland, as shown in disassembled form in **Figure 3**. It is important to ensure that the phono socket and the jack plug are made of metal (the BNC plug is only available in metal). Only parts of the three connectors are used: the shells of the phono coupler and jack plug, and the cable gland of the BNC plug.

The shell of the phono socket will later be used to hold the microphone insert after it has been removed from its enclosure. The internal diameter of the shell needs to be at most a few tenths of a millimetre smaller than the external diameter of the disassembled microphone. Hold the shell in a drill chuck and wrap a suitable dowel in grade 400 sandpaper. As in a lathe, the shell is reamed out as far as is necessary, taking care not to damage the thread. Next, cut down the shell of the jack plug, which must have the same diameter as the 'naked' microphone, to about 10 mm, and carefully smooth it off. **Figure 4** shows the individual parts of the new microphone enclosure in the order in which they are assembled.

Now the microphone is prepared. The rolled edge on the rear should be separated from the circuit board using a sharp craft knife. Ensure that you do not touch the microphone aperture, since the diaphragm is very easily damaged. Do not yet remove the microphone: first solder a shielded cable to the solder connections, observing their polarity.

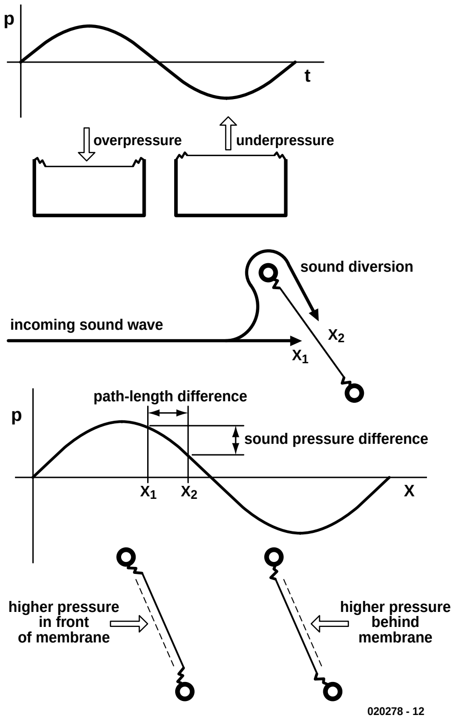

Figure 2. Pressure transducers and pressure gradient transducers compared.

Under cover

You now require a clean room, which can be improvised from a transparent refuse sack. Since dust, grease, dirt and electrical charge will all damage the diaphragm and the internal components of the capsule, earth yourself, slip on thin rubber gloves (without talcum powder!), and proceed to carry out the rest of the work in the clean room.

Hold the capsule vertically by its cable

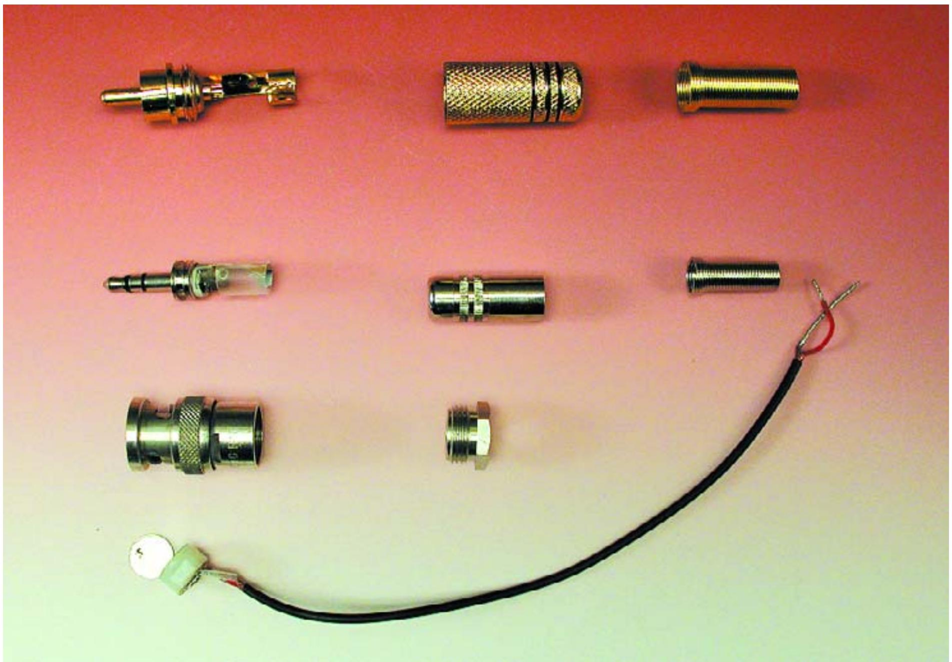

Figure 3. The three connectors used.

and carefully lift off the aluminium enclosure. Then, equally carefully, guide the shell of the phono socket over the capsule without touching the internal parts. The diaphragm insulating ring now lies against the internal edge of the shell which would normally hold the cable strain relief in the phono socket. Fit the sawn-off jack plug shell and fix it using the BNC cable gland (**Figure 5**).

The subsonic microphone, as we can now call it, can now be taken out of the clean room. The enclosure should now be adequately airtight to allow measurements in the subsonic range to be carried out. To make absolutely certain, use a needle to add a drop of solvent-free superglue at the point of contact between the shell and the insulating ring, taking care not to touch the diaphragm.

The open diaphragm is very fragile and must be shielded from dust and contact. To protect it, fit a suitable 20 mm length of plastic sheath over the front and fit a foam cap to the aperture.

Electronic amplification

The output voltage of a condenser microphone is not very high and must be amplified by a large factor before the signal can be processed further. The electronics for the initial impedance conversion, which takes place inside the capsule, requires a power supply which is provided in **Figure 6** by R1 and R2. The AC signal is taken from the microphone via coupling capacitor C3 to the first amplification stage IC1.A. The input impedance is set by R3, and the gain is given by 1+R5/R4. C4 limits the bandwidth of the amplifier and prevents instability. With a microphone voltage of –30 dBu to –70 dBu a gain of 34 is not adequate. A second amplification stage using IC1.B amplifies the signal by a further factor of 3.3 or 30. This gives a total gain of 100 (with S1 in the position shown) or 1000 (with S1 in the other position). This allows any readily-available electret microphone to be used (as long as it is the correct physical size), and the output of the circuit will provide a signal at line levels.

The dual opamp used is a precision device (i.e., with a low input offset voltage) from Maxim with a very low current consumption and so ideal for battery operation. The data sheet can be found at
http://pdfserv.maxim-ic.com/arpdf/MXL1178-MXL1179.pdf

To analyse the subsonic sound, connect the microphone preamplifier to the input of a sound card. A suitable program (with a free experimental version) for analysing oscillations and sounds is *Medusa*, which can be found at
www.maschinendynamik.de/index.html

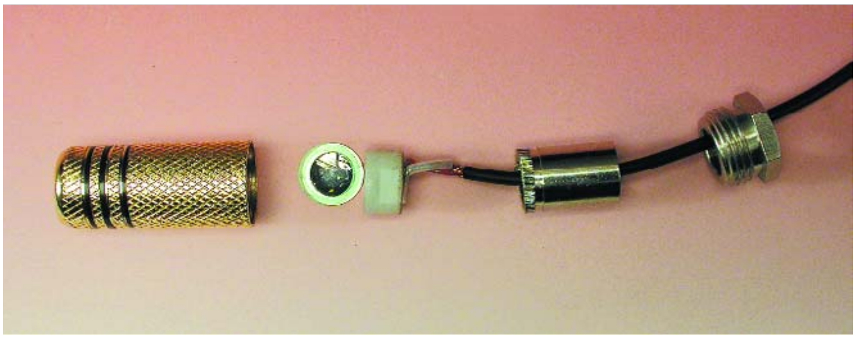

Figure 4. The prepared components.

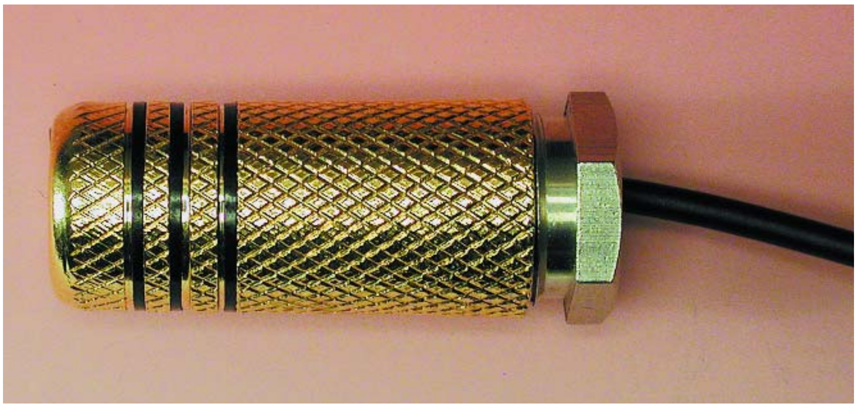

Figure 5. Assembly of the components in the clean room.

A guide to constructing this microphone can also be found on the Internet at the site of the German interest group for investigating low-frequency sounds (IGZAB) at
http://www.brummt.de

Microphones, microphone amplifiers and sound cards do not exhibit a flat frequency response in the range below 10 Hz. If you are not able to measure the transfer characteristics of the various parts of the

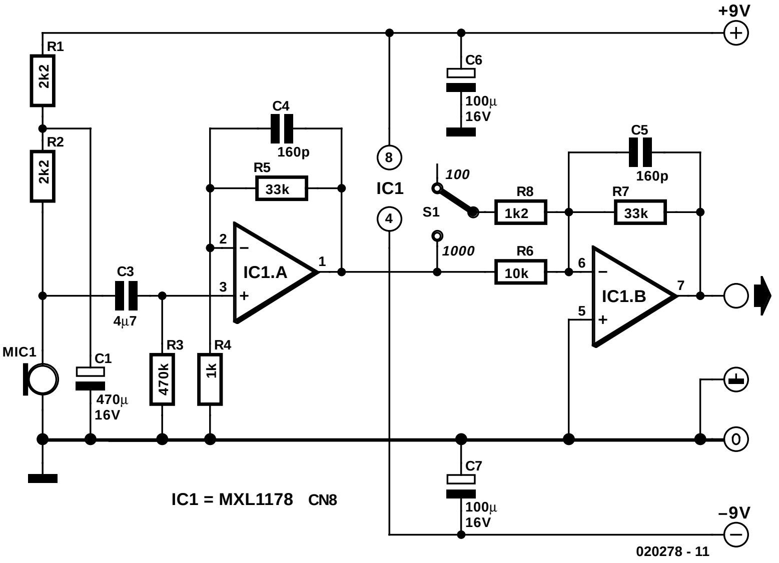

Figure 6. Circuit diagram of the microphone preamplifier.

measurement chain, you will only be able to work with estimated values.

The transfer characteristic of the subsonic microphone is not known and is therefore taken (rather optimistically) as 1. Correction factors for the microphone preamplifier used and for the (Terratec) sound card have been determined as shown in **Table 1**.

Of course, subsonic sounds can be recorded using an A-D converter instead of a sound card. The author used the *Edirol UA-1A USB Audio Interface* from Roland. This gave different correction factors, see **Table 2**. If the two inputs of the Edirol unit are used with two microphones mounted a set distance apart, it is possible to investigate techniques for locating the source of a sound.

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Table 1

Frequency (Hertz)	Correction factors			
	Subsonic microphone	Preamplifier	Terratec soundcard	Overall
10	1	1	1	1
4	1	1	0.62	1.6
2	1	1	0.37	2.7
1	1	1	0.25	4

Table 2

Frequency (Hertz)	Correction factors			
	Subsonic microphone	Preamplifier	Edirol UA-1A	Overall
10	1	1	1	1
4	1	1	0.94	1.1
2	1	1	0.85	1.2
1	1	1	0.73	1.4